Recommendation WG 03.10.001
(Replaces WG 14.87.011)

(Final)

MIXED HIGH-LOW FREQUENCY PLANS

(BUCKS)

and

REFLECTION INTERFERENCE

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RECOMMENDATION

Subject Area: Mixed High-Low Frequency Plans (Bucks) and Reflection Interference

Synopsis

This recommendation addresses coordination procedures that should be used to minimize reflection interference and coordinate discrepancy problems involving the mixing of high and low frequency plans (commonly referred to as a "bucking" situation). Frequency planners should make strong efforts to match the established/conventional frequency plans, where such convention exists. If the introduction of a mixed (i.e., opposite) plan is absolutely necessary, the initiating coordinator should work closely with other coordinators to predict any potential problems and avoid them in advance of construction. These same identification procedures should be used by coordinators in areas where mixed high-low plans already exist. After a facility has been constructed, if it causes immediate interference, the new entrant is generally responsible to resolve the problem, consistent with the "first come, first served" principle. If no interference issues are reported, the new facility derives the same continuing interference protection rights as any other successfully coordinated and licensed facility.

Background

The basic goal of frequency coordination is to enable the construction of new radio facilities with minimal impact on previously licensed or coordinated facilities. The prior coordination notification-and-response process represents an analytical attempt, sometimes supplemented by physical measurements, to control the predictable levels of interference.

Unfortunately, not all interference mechanisms are clearly predictable. Among other things, reflections from buildings or other objects are well known but generally unpredictable contributors to interference. It is generally considered that if reflection interference is found to occur following construction, the "last party in" (i.e., the last constructor) should assume responsibility for resolving the problem. This is consistent with the traditional "first come, first served" principle of frequency coordination and interference protection. Often the necessary modifications are expensive and, in some cases, newly constructed facilities may have to be completely redesigned or relocated. If and when the FCC is asked to assist in resolving reflection interference problems, the initial approach taken usually involves an attempt to have all affected parties somehow share the resolution burden. Operators of previously licensed facilities thus may face unexpected expense or new limitations on their abilities to expand their systems to their maximum capacities. In those cases in which no reasonable cooperative solution is available, the FCC will in the end usually require the "last party in" to assume sole responsibility for correcting the problem.

Microwave stations in urban areas are subject to a higher potential for reflection interference because of the existence of many tall buildings. Recognizing this fact, designers of microwave stations in urban areas have in the past often gravitated toward the use of frequency plans that avoid transmitting on the same frequencies that other urban area stations use for receiving. This minimizes the potential for relatively high-powered transmit signals to reflect off nearby buildings and interfere with relatively low-powered signals on the same frequency received by other urban area stations. It is important to recognize that mixed plan reflections result in interference to the stations at the distant ends of the paths terminating in the urban area. (See NSMA Report WG 8.93.009)

Nevertheless, closely located microwave stations in any area of the country have a higher potential for reflective interference. This is particularly worse when the same, overlapping, and adjacent channel frequencies are used for transmitting and receiving. In addition, closely located mixed plan stations can create problems due to receiver overload and other receiver interference issues. The interaction with surrounding objects, coordinate inaccuracies, and near field impacts all pose additional interference concerns.

In this regard, frequency planners should consider closely located microwave facilities to be similar to a junction station. Only in unusual circumstances and after careful planning would a planner attempt to use the same frequency for both transmission and reception (even on different paths) at a junction station. Although reflection problems are usually less severe in rural areas there is an increased potential for reflective interference when closely located stations are transmitting and receiving on the same or nearby frequencies.

The term "high-low plan" is generally used to relate to the use of different sets of frequencies for transmission and reception. In each of the 2, 4, 6.1, 6.7, 11, 18 and 23 GHz bands, high-low plans have been developed and are in common use. (Note that not all high-low plans actually involve the exclusive use of the high or low portion of a frequency band The plans used in the 4 GHz band serve as an example of such an exception, but these 4 GHz plans required extensive adjacent and semi-adjacent channel filtering, branching circuits and separate transmit / receive antennas due to the high/low mixture inherent in the plans.) This Recommendation primarily focuses on the frequency bands 6.1, 6.7, 11, 18 and 23 due to the limited activity in the 2 and 4 GHz terrestrial bands.

Reflection problems can occur as a new system is turned up or they can occur or be identified much later. For example, new building construction may create new reflection interference paths. In addition, the tearing down of an old building may create a reflection problem if the building formerly blocked a potential reflection path. Moreover, potential victims of reflection interference may not realize it if they are not yet using the particular frequencies of interest. Generally speaking, the later a reflection problem is identified, the more difficult and complex is its resolution.

While these problems can exist with consistent use of a high-low frequency plan, the use of a mix of opposite plans raises the potential for harmful reflection interference to other nearby systems. In addition, where mixed plans exist, subsequent coordination and construction of new facilities is more difficult, expensive and, because of the possibility of unpredicted reflection interference, more risky. It is thus to the mutual benefit of coordinators and licensees to make special efforts during the prior coordination stage to match established high-low plans whenever possible.

Additional factors in locating mixed-plan facilities close together are the impact of near field antenna issues and coordinate discrepancies. The issues with the Far Field Distance should be approached by considering all licensees at the desired location and the potential for creating bucks with anyone locating in the respective band. The following table provides calculations of the Far Field distance for the 6 GHz and higher point-to-point microwave bands:

Far Field Distance Calculations

Formula: $D(f) = 2d^2/\lambda$ (From "Microwave System Engineering", DJ Collins, 1976, Page 146)

where D(f) = Far Field Distance in Meters
d = Antenna Diameter in Meters
λ = Wavelength in Meters.

Antenna Size:

Feet	2	4	6	8	10	12
Meters	0.61	1.219	1.829	2.438	3.048	3.658

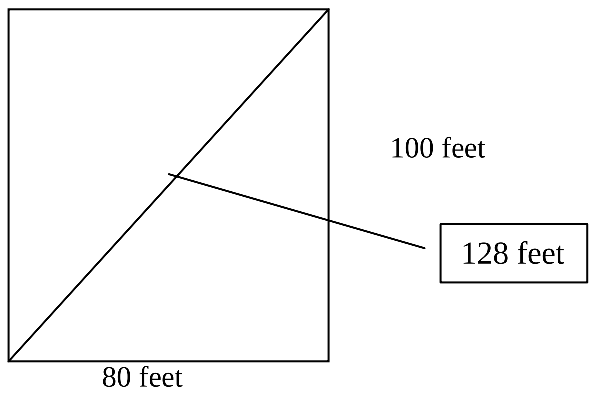
Far Field Distances:

Freq MHz	Wave Length (λ) [meters]	2 – Foot Antenna Far Field Distance D(f) [meters]	4 - Foot Antenna Far Field Distance D(f) [meters]	6 – Foot Antenna Far Field Distance D(f) [meters]	8 - Foot Antenna Far Field Distance D(f) [meters]	10 - Foot Antenna Far Field Distance D(f) [meters]	12 – Foot Antenna Far Field Distance D(f) [meters]
5925	0.0506	14.71	58.74	132.23	234.94	367.22	528.91
6175	0.0486	15.32	61.17	137.71	244.69	382.45	550.85
6425	0.0467	15.94	63.65	143.29	254.59	397.93	573.15
6525	0.0460	16.20	64.68	145.62	258.74	404.41	582.48
6700	0.0448	16.63	66.42	149.52	265.68	415.26	598.10
6875	0.0436	17.07	68.15	153.43	272.62	426.10	613.72
10600	0.0283	26.31	105.08	236.56	420.33	656.98	946.25
10950	0.0274	27.21	108.67	244.64	434.68	679.41	978.57
11300	0.0265	28.05	112.02	252.19	448.08	700.36	1008.74
11700	0.0256	29.04	115.99	261.11	463.95	725.15	1044.45
17700	0.0169	43.94	175.47	395.02	701.88	1097.04	1580.09
18500	0.0162	45.92	183.40	412.87	733.58	1146.60	1651.46
19700	0.0152	48.90	195.29	439.64	781.16	1220.96	1758.57
21200	0.0141	52.63	210.16	473.13	840.65	1313.95	1892.51
22000	0.0136	54.61	218.09	490.97	872.36	1363.51	1963.89
23600	0.0127	58.58	233.95	526.69	935.82	1462.69	2106.74

Grayed Areas - Calculated for reference, few paths exist with the respective antenna size/band

Coordinate Inaccuracy Allowance

Since the coordinate accuracy required by the FCC is within one second, the corresponding potential error distance needs to be considered in order to establish the guideline. For a difference of latitude, the incremental distance is approximately 100 feet per second, while for a difference of longitude the distance varies by location but 80 feet per second is an approximate average value for the continental United States. Using these nominal distance increments and the pythagorean theorem, the actual location of a site that complies with the FCC coordinate accuracy requirements may be up to 128 feet from its licensed coordinates for the maximum error of one second latitude and one second longitude.



The error distance 128 feet converts to approximately 39 meters, and considering both sites involved, the allowance would be doubled for a value of 78 meters. An additional allowance of 39 meters should be included for the 18 and 23 GHz paths to allow for the short path distances and the corresponding severe impact that coordinate inaccuracies have on the interference considerations. Without surveyed or satellite confirmation of the exact location of the sites, it may be necessary to expand this distance to allow for greater location inaccuracies.

Future Case Resolution Considerations

Due to microwave system design constraints frequency coordinators may be forced into finding and selecting a "bucking" frequency. They select the frequency based on interference calculations using data that has been filed with the FCC which has good accuracy for items such as coordinates, elevations, antenna heights, transmit powers, etc. However, the accuracy of the data even if the FCC and FAA standards are met may not be precise enough to definitively guarantee that installing a bucking frequency will not cause harmful interference. Even if the parameters outlined in this document are followed, there is no absolute guarantee that interference will not occur from the installation of a bucking frequency.

The frequency coordinator proposing the bucking frequency assignment should notify their customer that interference is always possible. Therefore, in the event that existing users begin noticing interference either immediately or at a later date the cooperation between incumbent users and new licensee is paramount. In order to find the cause of the interference they should cooperate fully with the existing companies at the site.

Stated another way, interference caused by the installation of a bucking frequency at a site may not be detected for several months since it may be in the form of dribbling errors and in fact may be intermittent. Once an incumbent company detects the interference the company that installed the bucking channel is expected to cooperate with the incumbent.

Recommendation

Recognizing these problems, we recommend that frequency planners make strong efforts to avoid introducing an opposite high-low plan (a buck) where an established plan is in place. These efforts should include changing antennas, frequency bands, locations, adding a mid-point site to be able to flip the plan, and other possible techniques to eliminate the buck. It is considered sound engineering practice to match the established plan in an area in order to limit reflections and other interference issues.

As noted earlier, the extent of the transition zone, and therefore the potential for interference, increases with increasing frequency if the antenna size is held constant. The potential for interference due to coordinate discrepancies increases with decreasing path length and the potential for interference due to reflections decreases with decreasing beamwidth. However, a methodology has not been developed to fully quantify these effects. Additionally, there are other variables that affect the potential for "bucking" interference that cannot be easily accounted for such as the location and quantity of reflective surfaces.

The following distances were selected in an attempt to maximize spectrum usage while minimizing the potential for interference to existing systems due to reflections, transition zone and coordinate uncertainties. The listed values represent a consensus of recommendations from the participating frequency coordinators and spectrum managers.

Minimum Guideline Distances for considering bucking situations:

6.1 – 6.7 GHz	(5925 – 6875 MHz)	0.750 km	(0.466 miles)
10 – 11 GHz	(10550 - 11700 MHz)	0.550 km	(0.342 miles)
18 GHz	(17700 – 19700 MHz)	0.350 km	(0.217 miles)
23 GHz	(21200 – 23600 MHz)	0.300 km	(0.186 miles)

However, after exhausting conventional design alternatives, a planner may find it necessary to buck the existing plan. In this case and in the situation with an existing mixed plan site - the frequency planner should maximize frequency separation from the facilities that are being bucked, consider cross polarization, and attempt to match the predominate plan in a mixed case. The planner should attempt to identify potential reflection problems and discuss them with other affected operators, either before or during the prior coordination stage. In addition, the potentially affected operators should themselves attempt similar analyses.

It should be recognized that, regardless of the particular frequency plan, once a facility has been successfully coordinated, constructed and found not to cause immediate interference, it deserves the same coordination protection considerations as other facilities. With this in mind, and noting that many areas already have mixed frequency plans in use, planners of new facilities in already mixed areas should follow the identification-and-analysis guidelines described above. In addition, should a reflection problem subsequently result solely from changes in the physical environment (as opposed to radio construction), the affected radio operators should cooperatively assume responsibility for resolving the problem.

Additional point-to-point bands with high-low frequency plans may be allocated in the future. Frequency plans accompanying these new allocations should follow this recommendation in order to minimize potential bucking situations. Until an industry consensus is reached on any new bands, the minimum guideline distances that should be used are as follows:

Below 6.1 GHz - 0.750 km (0.466 miles) should be used as the guideline distance

Between 6.1 & 23 GHz - linear interpolation can be used to estimate a guideline based on the established distances

Above 23 GHz - NSMA will develop guidelines when new bands are approved.
Co-location of mixed plan operations should be limited

The following sections summarize the responsibilities of the different parties, both during coordination and following turn-up of a new facility that might involve reflection interference:

During the prior coordination stage:

A - Responsibilities of the Initiating Coordinator:

I. To make strong efforts to avoid introducing a buck in an area where an established plan exists
II. To maximize frequency separation when introducing a new buck or adding frequencies to a mixed plan site
III. To make strong efforts to match the predominating plan when adding frequencies to a mixed plan site.
IV. To work closely with other coordinators to predict any potential reflection interference problems and avoid them in advance of construction.
V. Provide a technical contact to support any testing, monitoring, or other efforts in regard to the potential interference issues. *

B - Responsibilities of the Receiving Coordinator or Licensee:

I. To attempt to identify potential reflection problems related to the use of mixed frequency plans during the coordination process. This analysis should include existing facilities as well as any previously coordinated (future) channels or systems.

II. Verify the accuracy of the coordinates for their client's site, or provide updated coordinates to assist with a more in-depth interference analysis (if requested).

C - After Construction of the New Facility and Resolution of Any Issues Reported During Coordination:

I. Any interference experienced should be promptly brought to the attention of the new licensee, who bears responsibility to resolve any reflection interference problems in the physical environment as it exists at the time of new system turn-up.
II. Should any subsequent building construction (or destruction) activity result in reflection interference, the affected parties should resolve the problem on a cooperative basis.

Note: * Testing may be proposed by either party. If recommending or agreeing to reciprocal or other testing methods to resolve the bucking issues, the parties should agree upon a detailed testing procedure. See additional testing information in Addendum 2, NSMA WG#4 Recommendations and Harris Stratex Doc. No. 459, March 1996.

Addendum 1

Bucking Coordination Process Flow

1. Coordinator determines existing High-Low plan for sites in their proposed system using the distance guidelines in this document.
2. Coordinator designates High-Low plan to minimize the number of bucking cases with incumbent licensees.
3. If bucking is required, coordinator informs client about the potential ramifications of a bucking installation (additional costs, delays, potential testing requirements, and potential changes in system due to test results) and discusses with client whether it is reasonable to re-route or use other frequency bands to avoid bucking.
4. If re-routing or changing frequencies are not reasonable alternatives, coordinator verifies the geographic coordinates for the new entrant at the "bucking" site(s) either with a satellite image, certification letter, or site survey.
5. Perform interference analysis.
6. Does interference analysis yield non-interfering frequencies? If no, change high-low plan to buck at another site (back to #4)
7. Is there adequate frequency separation (2^{nd} adjacent minimum)? If yes go to step #12.
8. If not, coordinator requests their client visually verify if the path azimuth is clear of objects that could cause close-in reflections.
9. If possible, confirm transmit coordinates of co-channel and adjacent channel incumbents.
10. Select frequency with optimum azimuth angle and distance separation from co-channel and adjacent channel licensees.
11. If azimuth and distance are adequate, continue. If not, then change high-low plan to buck at another site(s) (back to #4).
12. Issue bucking coordination.
13. If bucking objections are raised during the coordination process and incumbent licensee shows a reasonable cause for concern, new entrant should provide coordinate verification and allow incumbent licensee the opportunity to provide updated coordinates.
14. If updated coordinates are provided, re-evaluate interference potential.
15. If new coordinates show potential for interference, cancel coordination, (back to #4)
16. New entrant agrees to pre-service testing upon completion of the installation and accepts responsibility for interference problems identified during the test.
17. Incumbent licensee should then remove objection and agree to test.
18. New entrant and incumbent licensee can then decide on a testing procedure and schedule that minimizes delays and expenses, but provides a reasonable assurance of interference free operation.
19. Is interference noted? If no go to 21.
20. Can system parameters be modified to eliminate the interference issue (better antennas, shielding) if yes re-schedule the test. If this is not possible new entrant should abandon the link and go back to (step #4)
21. New entrant may then place their link in service.
22. If an interference issue is identified at a later date, both parties should be reasonable and cooperate to determine the cause of the interference and work together to correct the issue.

Addendum 2
Outline of a Generic Reciprocal Test Plan for Measuring
A Proposed Microwave Bucking Station

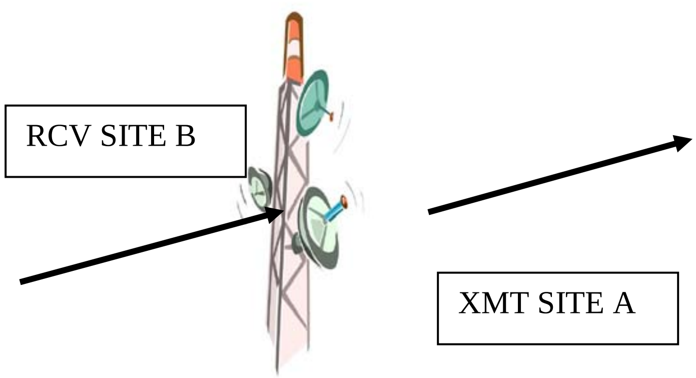
Overview

A microwave bucking station is defined as any location where a co-located, or closely located, transmitter and non-associated receiver are sharing the same half of the microwave band in any band that uses a high-low frequency configuration. This outline presents a generic test plan for performing measurements to determine if a proposed bucking installation will cause harmful interference. Testing is recommended for co-channel zero-distance bucks (same or immediately adjacent structures), but should not be limited to this situation. Other situations may benefit from testing as agreed to by the licenses.

Assumptions

1. The transmitter of the Incumbent bucking site is active, operating in the same frequency band as the proposed buck, and using the same antenna for transmitting and receiving.
2. The transmitting antenna is radiating in the precise azimuth as the proposed bucking situation.
3. The receive antenna of the New bucking path is installed at its proposed height, polarization, and is oriented in its proposed azimuth of operation situation.

For the purposes of this outline, the Incumbent transmit antenna will be referred to as the A site and the receive antenna will be referred to as the B site, as shown below.



General Measurement Procedure

1. Prior to performing the measurements, insure that the transmitter associated with Receive Site B is shutdown so that Receive Site B is in a receive-only mode.

2. At Receive Site B, disconnect the primary or diversity waveguide/transmission line at the input of the receiver and attach a spectrum analyzer tuned to the frequency of interest (the transmit frequency of Transmit Site A.

3. Using a 1 MHz measurement bandwidth, measure the level of the Transmit Site A signal as detected at the Receive Site B input to the receiver.

4. If the Transmit Site A signal is not detected, attach an LNA to the system to increase the measurement sensitivity and measure the level of the Transmit Site A signal as detected at the Receive Site B input to the receiver.

Calculation of Interference Signal Level

1. If the Transmit Site A signal is an analog signal, the measured signal level is the actual receive signal level that will be present at the Receive Site B input to the radio receiver.

2. If the Transmit Site A signal is a digital signal, correct the measured level in the 1 MHz measurement bandwidth by the factor of 10 Log (bandwidth of Transmit Site A signal in MHz / 1 MHz). This factor will be added to the measured level of Transmit Site A to determine the actual level that will be present at the Receive Site B input to the radio receiver.

3. Compare the Transmit Site A corrected receive signal level at the input to the Receive Site B radio with the appropriate C/I ratio for an analog receiver or T/I for a digital receiver to determine if the measured level meets the appropriate objective.

4. The results of the test including setup, procedure, spectral photos, calculations, and conclusions should be provided to the incumbent licensee and coordinators.

This generic test plan will provide valuable information regarding the actual coupling between the Incumbent Transmit Site A and the New Receive Site B systems in a co-located, or closely located, bucking situation. Additional testing or considerations may be necessary to fully determine the impact of the bucking situation. These efforts should be coordinated with the Incumbent licensee.

In any facility where the transmitter of Transmit Site A and the receiver of Receive Site B are in close proximity within the same physical structure and operating on the same or overlapping frequencies, use of specialized techniques may be required to prevent unwanted interference coupling. As well as the relative positioning of the equipment, additional shielding of transmission equipment and transmission line components of both the incumbent and new entrant may be required. Because shielding effectiveness can change over time, configurations that initially require exceptional amounts of mitigation efforts to limit harmful interference should be avoided when possible.