Recommendation WG 18.91.032

AUTOMATIC TRANSMIT POWER CONTROL (ATPC)

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RECOMMENDATION

Subject: Coordination

Title: Automatic Transmit Power Control

I. Introduction

Automatic Transmit Power Control (ATPC) is a feature of a digital microwave radio link that adjusts transmitter output power based on the varying signal level at the receiver. ATPC allows the transmitter to operate at less than maximum power for most of the time; when fading conditions occur, transmit power will be increased as needed until the maximum is reached. An ATPC equipped system has several potential advantages over a fixed transmit power system, including less transmitter power consumption, longer amplifier component life, and reduced interference into other microwave systems.

If the maximum transmit power in a ATPC system is needed for only a short period of time, a transmit power less than maximum may (if certain requirements are met) be used when interference calculations are made into other systems. On the other hand, because the maximum power is available when deep fades occur, C/I interference calculations into the ATPC system may assume the "maximum power" carrier level. Thus, ATPC usage may offer an advantage in the resolution of low level interference cases without compromise to the fade margin of the ATPC equipped system.

This Recommendation defines terminology, sets restrictions, specifies how ATPC systems will be coordinated, and establishes some ATPC operating guidelines.

II. Definitions

y	:The difference in an instantaneous transmit power and the selected Coordinated Transmit Power (defined below) in dB.
Tc(y)	:The calculated annual percentage of time that the ATPC system transmit power will exceed the selected Coordinated Transmit Power by y dB.
Tp(y)	:The maximum annual percentage of time yearly that the ATPC system transmit power is allowed to exceed the selected Coordinated Transmit Power (defined below) plus y dB. Calculated time percentages, Tc(y), should be less than Tp(y) for all values of transmit power.
Coordinated Transmit Power - Pc	:A transmit power selected by the ATPC system owner during coordination. This power, based on standard path calculations or path performance monitoring system results, will not be exceeded for more than Tp(0) percentage of time annually. Also, the power must be within (or at) the limits set by the Nominal and Maximum Transmit Powers (discussed below).

Maximum Transmit Power - Pmax	:The transmit power which will not be exceeded at any time. This power usually would be limited by the operational characteristics of the final amplifier; however, if interference cases do not allow the full amplifier power to be reached, a lesser value would be set at the transmitter.
Nominal Transmit Power - Pnom	:The transmit power at which the system will operate in normal unfaded conditions. This power must be less than or equal to the Coordinated Transmit Power.
F(P)	:Depth of path fade (as measured at the control receiver) required to cause the controlled transmitter to reach the output power P.
F(P>Pc)	:Fade depth which causes the Coordinated Transmit Power to be exceeded.
F(Pmax)	:Fade depth which causes the Maximum Transmit Power to be reached.

III. <u>Restrictions</u>

Tp(y)	:Defined in the Attachment to this Recommendation for for O <= y <= 10 dB.
End Points of Tp(y) Tp(0dB) = 0.50%	:This is the maximum annual time percentage that the Coordinated Transmit Power may be exceeded.
Tp(l0dB) = 0.01%	:This is the maximum annual time percentage that the transmit power is permitted to exceed the Coordinated Transmit Power by 10dB.
Pmax < = Pc + 10 dB	:The Maximum Transmit Power cannot be more than 10dB greater than Pc, the Coordinated Transmit Power.
F(P>Pc) > = 10 dB	:The fade depth which causes the transmit power to exceed the Coordinated Transmit Power must be at least 10 dB.
Tc(y) < =Tp(y) for y > 0 dB	:The calculated annual time percentage for all positive values of y must be less than the permitted annual time percentages.

IV. <u>Calculation Methodology</u>

1. Calculation of annual percentages of multipath fading should use a standard mathematical model, such as described by A. Vigants in the Bell System Technical Journal, January, 1975. Multipath models have usually only been validated for moderate fade depths; thus the F(P>Pc) restriction must be met, even if the model shows a lesser fade would also make Tc(y=0) < Tp(y=0).

2. For systems with space diversity, calculated diversity improvement factors less than 1.0 (common for shallow fades) should be set to 1.0. For a space diversity improvement factor to be applicable, the

ATPC system must be controlled (within applicable fade depth range) by the combined signal or the stronger signal from the two antenna system.

3. Angle diversity systems should assume no diversity improvement factor.

4. Other forms of fading, such as rain fade or obstruction fade, will also cause the ATPC system to increase transmit power. Paths with inadequate clearance or long paths above 10 GHz may have to provide additional justification (beyond the multipath fading calculations) for claiming a Pc less than Pmax.

V. <u>Coordination</u>

1. During the coordination process, the user of ATPC should clearly state that ATPC is in use. Accompanying the coordination should be an ATPC Attachment which specifies ATPC operational parameters. In addition, time percentage calculation assumptions and results should be shown. An example ATPC Attachment is included in this Recommendation.

2. Interference calculations into the receiver of an ATPC equipped system should assume that the Maximum Transmit Power is in use. Thus, in calculating a C/I for comparison to the objectives, the "C" should be based on the Pmax.

3. Certain earth station systems may not have ample fade margin to tolerate the maximum power increase above the ATPC Coordinated Power, especially when the interfering path is line-of-sight. Additional justification (such as path loss measurements and/or antenna pattern verification) may be requested in these cases.

4. If the restrictions in this Recommendation have been met, interference from an ATPC equipped transmitter should be calculated using the Coordinated Transmit Power (not the Maximum Transmit Power).

5. Just as questions related to an OH Loss calculation may lead to a request for blockage verification or an interference measurement, the coordination of an ATPC equipped system may require follow-up. In some cases, verification of "worst-month" fading characteristics of the ATPC equipped path may be needed.

VI. <u>Operational Guidelines</u>

1. Continuous operation at Maximum Transmit Power for a 5 minute period may imply an equipment failure. This situation should result in an alarm condition which returns the transmit power to (or below) the coordinated power.

2. When practical, ATPC should be used in a conservative manner. For example, selection of the Nominal Power below the Coordinated Transmit Power will help offset the increase in interference as the transmit power increases above the Coordinated Transmit Power.

VII. <u>Examples of ATPC Application</u>

The following examples illustrate valid application of ATPC systems according to the restrictions above:

1. A path designer wishes to apply ATPC (instead of changing-out existing antennas) in order to reduce intrasystem interference at a junction station. The 6 GHz path being added from the junction will be 16 miles in length with space diversity separation of 35 feet; the path is in a difficult propagation area (climate = 2), with average terrain roughness (w = 70 ft).

Standard flat fading calculations show a combined (main and diversity) fade depth of 8 dB or greater will occur for 0.50% of the time and a combined fade depth of 20 dB or greater will occur for 0.01% of the time. This Recommendation requires that at least a 10 dB fade must occur before Coordinated Power is exceeded. (Note that no space diversity improvement is assumed at such shallow fades.) Thus, for this path, the minimum fade parameters that could be chosen would be:

F(P > Pc) = 10 dB and F(Pmax) = 20 dB.

However, for this relatively short path, a rather high flat-fade margin is available. In order to be more conservative, larger fade depths are chosen.

Final parameters are chosen as shown below.

Fade Depths:
F(P > Pc) = 15 dB
F(Pmax) = 25 dB

Transmit Powers:
Pnom = 22 dB
Pc = 22 dB
Pmax = 32 dB

Time Percentages:

Tc(y= 0 dB) = 0.1% < Tp(0 dB) = 0.50 %
Tc(y=10 dB) = 0.001% < Tp(10 dB) = 0.01 %

and therefore,
Tc(y) < Tp(y) for all y in the range (0 dB < y < = 10 dB).

2. A path designer wishes to use ATPC on a 6 GHz path which does not use space diversity. The 18.0 mile path is very smooth, in an average climate. Standard multipath calculations show that a 12 dB fade (or greater) will occur for 0.47% of the time and a 29 dB fade (or greater) will occur for 0.01% of the time. Because of design considerations, however, only a 24 dB fade can be tolerated before maximum transmit power (+30 dBm) is reached.

Calculations show that a fade greater than 24 dB occurs for 0.03% of the time on this path. Tp(y = +7 dB) = 0.032%, thus a transmit power of 30 dBm (which is reached at a fade depth of 24 dB) may be a maximum of 7 dB above the Coordinated Transmit Power.

The ATPC system in use increases power 1 dB for each 1 dB of fade beyond the point at which the Nominal Transmit Power is exceeded.

Using the symbols defined in this Recommendation, the designer makes the following choices:

Transmit Powers:

Pnom = 20 dBm
Pc = 23 dBm
Pmax = 30 dBm

Fade Depths:

F(P > Pnom) = 14 dB
F(P > Pc) = 17 dB
F(Pmax) = 24 dB

Time Percentages:

Tc(y= 0 dB)= 0.15 % < Tp(0 dB) = 0.15 %
Tc(y= 7 dB)= 0.03 % < Tp(7 dB) = 0.032 %

Because power is increased 1 dB for each 1 dB of fade depth (beyond 14 dB) until the maximum power is reached, Tc(y) < Tp(y) for all y within the operating range (0 dB < y < = 7 dB).

3. A 6 GHz path is 32 miles long with slightly above average terrain and climate parameters. Space diversity is employed with 35 feet of separation. Calculations show that a combined 17 dB fade or greater will occur for 0.50 % of the time. However, in order to minimize ATPC activity, the designer chooses to wait until a combined 21 dB fade has occurred before increasing the transmit power above the nominal.

The ATPC equipment to be used allows selection of power application slope. Transmit power is chosen to increase 2 dB for every 1 dB of combined fade depth beyond 21 dB. The Nominal Transmit Power is chosen to be equal to the Coordinated Transmit Power; the Maximum Transmit Power is to be 10 dB above Coordinated Power.

Transmit Powers:

Pnom = 23 dBm
Pc = 23 dBm
Pmax = 33 dBm

Fade Depths:

F(P > Pnom) = 21 dB
F(P>Pc) = 21 dB
F(Pmax) = 26 dB

Time Percentages:

Tc(y= 0 dB)= 0.10 % < Tp(0 dB) = 0.50 %

Tc(y=10 dB)= 0.01 % < = Tp(10 dB) = 0.01 %

and therefore,

Tc(y) < Tp(y) for all y in the range (0 dB < y < = 10 dB).

VII. <u>Examples of ATPC Application</u> (cont'd)

4. The designer of an 11 GHz path wishes to employ ATPC to increase transmit power during severe rain-fading. Running a continuous high power level would risk receiver overloading during up-fading conditions. Although ATPC will be used, no coordination advantage is to be claimed. (The operator of the path wishes to maintain flexibility to adjust ATPC parameters.)

Because ATPC is to be used, the coordination could show the following:

Transmit Powers:

Pnom	= 23 dBm
Pc	= 33 dBm (no coordination advantage claimed)
Pmax	= 33 dBm

Fade Depths:

F(P > Pnom)	= N/A
F(P > Pc)	= N/A
F(Pmax)	= N/A

Time Percentages:

Tc(y= 0 dB)	= N/A
Tc(y=10 dB)	= N/A

This type of coordination would simply document that ATPC is in use and would specify the Nominal Transmit Power. In doing interference calculations into other systems, the Maximum Transmit Power (Pmax) should be used. If the system owner wished to eliminate the ATPC feature, a new coordination should be issued; however, because no coordination advantage had been claimed, no new cases should appear.

VIII. References

1. A. Vigants, "Space-Diversity Engineering," The Bell System Technical, Vol. 54, No. 1 (January 1975), pp. 103-142.

Attachment Specification of Tp(y)

Tp(y) restricts the time percentage that the ATPC transmitter is permitted to exceed the selected Coordinated Transmit Power by y (in dB). According to restrictions given in the Recommendation, only values of y less than or equal to 10 dB are permitted.

$$Tp(y) = Tp(0)\ 10^{-Q \cdot y} \quad , \text{ for } 0 \text{ dB} < y < 10 \text{ dB}$$

$$\text{Where } Q = 0.1 \log [Tp(10 \text{ dB}) / Tp(0 \text{ dB})]$$

As defined in the body of this Recommendation,

$$Tp(0) = 0.50 \quad (\%)$$

$$Tp(10 \text{ dB}) = 0.01 \quad (\%)$$

thus,

$$Q = 0.17$$

and,

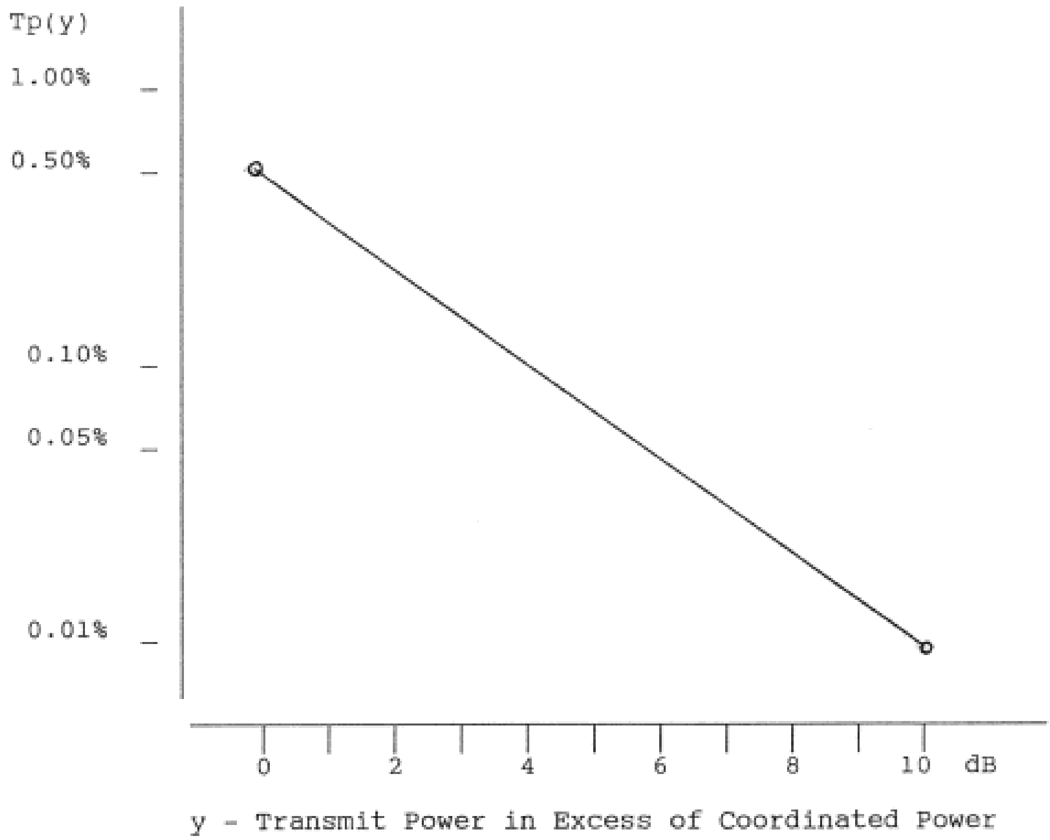
$$Tp(y) = 0.50 \bullet 10^{-0.17y} \quad (\%)$$

In dB steps above the selected Coordinated Transmit Power, the permitted time percentage is:

>0.0 dB	= 0.50	%
1.0 dB	= 0.33	%
2.0 dB	= 0.22	%
3.0 dB	= 0.15	%
4.0 dB	= 0.10	%
5.0 dB	= 0.070	%
6.0 dB	= 0.047	%
7.0 dB	= 0.032	%
8.0 dB	= 0.021	%
9.0 dB	= 0.014	%
10.0 dB	= 0.010	%

A plot of the Tp(y) curve is shown on the next page.

Plot of Tp(y), for 0 dB < y <= 10 dB



Attachment: Sample Coordination Format

Automatic Transmit Power Control(ATPC)Attachment North American Telecom

	Site 1	Site 2	Notation
Site Name	North Hill, PA	Twin Lake, PA	
Path Data			
Path Distance	26.3mi		=D
Roughness	> 140.0 ft		=w
Climate	1.0		=clim
Terrain/Climate Factor	0.26		=c
Frequency	3.95 GHz		=f
Antenna Data			
Diversity Type	Space	Space	=SD
Relative Gain	1.0	1.0	=v
Spacing	30.0 ft	30.0 ft	=s
Path Clearance	> 0.4 F1	> 0.4 F1	
at K-factor	0.667	>0.667	
Antenna Path	Tx(2) -> Main(l)	Tx(1) -> Main(2)	
Path Clearance	> 0.3 F1	> 0.1 F1	
at K-factor	0.667	>0.667	
Antenna Path	Tx(2) -> Div(l)	Tx(1) -> Div(2)	
Transmit Power			=p
Nominal	22.0 dBm	16.0 dBm	=Pnom
Coordinated	22.0 dBm	16.0 dBm	=Pc
Maximum	32.0 dBm	26.0 dBm	=Pmax
ATPC Algorithm	Linear	Linear	
Fade Depth			=F(P)
for P > Pcoord	> 12.0 dB	> 12.0 dB	=F(Pc)
for P = Pmax	> 22.0 dB	> 22.0 dB	=F(Pmax)
SD Improvement			=DI
Factor at FDcoord	1.0	1.0	=DIcoord
at FDmax	1.5	1.5	=DImax
Calculated Time %			=Tc
for P > Pcoord	0.07 %	0.07 %	=Tc(0)
for P = Pmax	0.005%	w/SD 0.005%	=Tc(Pmax-Pc)

Fade Depth Time Percentage - Calculation Methodology

w = roughness - see Reference
L = antilog(-FD/20)
clim= .5 (dry), 1 (average), 2 (humid)
c = clim x (w/50)^-1.3
r = 0.25 x c x f x (DxDxD) x 10^-05

Single Antenna (non-diversity)

T = 0.25 x r x L x L; percent yearly, based on 3 worst months

With Space Diversity

v = relative antenna gain - see Reference
q = v x s / L; (s < 50)
DI = 7.0 x 10^-05 x q x q x f / D; if DI < 1.0, then set DI = 1.0
Tsd = T / DI;

Reference: Space-Diversity Engineering, A. Vigants, BSTJ, January, 1975

Objectives: Tc(0 dB) < 0.50% , Tc(10 dB = pmax-pc) < 0.01%
Tc(y) < Tp(y) , for 0 dB <= y <= 10 dB - see NSMA ATPC Rec.

Notes :

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