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National Telecommunications& Information Agency
Mr. Milton Brown, Office of the Chief. Concil,
Room 1413

By FAX: **1 202-501-8013**

Re: Docket Number 060512129-6129-01

Subject Coupon Program, DTV Downconverters

Dear Sir:

Please allow me to introduce myself. I am a technical staff writer for TV TECHNOLOGY, a trade magazine. My specialty is DTV transmission & reception. My qualification is experience gained during the ten years in which I was the Chief Scientist of the Advanced Television Center Inc which tested the DTV System adopted by the FCC in 1996, and in the past decade I have done original experimental work investigating digital signal transmission in my own laboratory. A list of technical papers I authored, or co-authored published in "IEEE Transactions on Broadcasting" and IEEE Transactions on Consumer Electronics is attached following my comments being filed today. I am otherwise retired and am writing you as a concerned citizen anxious to see that this DTV downconverter program is effective, not a waste of funds. I shall confine my comments to my particular field; testing of DTV systems.

The NPRM in section E. *Digital-to-Analog Converter Box* indicates that the ATSC document A/74 Receiver Performance Guidelines (dated June 18, 2004) will be the basis for setting minimum performance standards for such Boxes as may be eligible for federal subsidy. While there must be a set of minimum performance standards to qualify product for this subsidy, however the A/74 document was never intended to serve as a minimum performance standard, it is just what its name indicates, guidelines and not a standard.

In fact, these guidelines are at odds with many of the FCC DTV Planning Factors now embodied in its Rules, Part 73. These Planning Factors would serve the public better as the basis for your minimum performance standards. For example the minimum usable DTV signal power at the input of DTV receivers at the edge of the station's noise-limited coverage is – 84 dBm. ATSC doc. A/74 indicates in section 4.1 (page 11) from – 83 dBm. It is easier and cheaper to manufacture a receiver with an 8 dB noise Figure than for a 7 dB Noise Figure, which is the FCC Planning Factor for UHF DTV channels. In any case, the minimum usable DTV signal power at the receiver input is – 84 dBm by the Planning Factors of the FCC. Receivers with a higher minimum usable signal power (- 83 dBm or higher yet) will not be usable at the edge of the station's noise-limited contour depriving some citizens of programming from said station.

While analog TV picture quality degrades gradually as the signal grows weaker, usually with greater distance, there is no degradation in picture quality at low signal levels for DTV until the threshold signal-to-noise power (15.2 dB) is reached. At that threshold, reception fails abruptly, no picture, no sound, no service. Thus weak signals must always be above the threshold, that is they must exceed the FCC – 84 dBm threshold level.

Measuring the Minimum Signal Power for DTV reception

I suggest a testing method to measure the minimum usable DTV signal power at the receiver input. The test signal can be obtained from any commercially available ATSC Exciter, (a component of DTV transmitters) when fed the ATSC Transport data stream as is shown in Figure 1. Only the desired signal must be actual program material from a valid ATSC transport stream. Exciters can be programmed to provide the DTV signal on any US TV channel. The power from the Exciter is attenuated by a suitable wideband calibrated attenuator and fed directly to the antenna connector of the downconverter under test (DUT). With appropriate attenuator settings, the power to the DUT is – 86 dBm, 2 dB below the threshold of – 84 dBm. As the signal is below threshold, it will not operate. Now increase the signal power in (say) 0.5 dB steps to – 85.5 dBm, - 85.0dBm, - 84.5 dBm. until the receiver produces pictures and sound in a stable manner. You have found the minimum usable signal power of that receiver on the test channel.

Measuring the Maximum Signal Power for DTV reception

The measurement set-up is shown in Figure 1.

There is also an upper bound on the useable signal power input to a receiver. Above this power, the receiver is overloaded and will not produce pictures or sound. The method of measurement is to decrease the attenuation (see above) so that the signal at the receiver is 0 dBm which I am sure will overload any receiver. Now decrease the signal power in (say) -0.5 dB steps until the receiver operates normally stable picture and sound. You have found the maximum power the receiver can receive.

Some useful information about the maximum received DTV signal power to be expected near transmitters is found in Appendix D of ATSC doc A/74. See

Table D.1 Here we find powers of -8 dBm, - 7 dBm and – 5 dBm at the sample site a few miles from the transmitters. In the future, some stations may seek to increase their radiated power so even – 5 dBm may be a conservative maximum signal power level. Even so, I would use – 5 dBm for your purposes.

Designers of receivers can trade off good noise performance (low minimum signal power required) against signal overloading by strong signals. Thus both measurements must be made to properly characterize the product.

Please note that it is good engineering practice to turn off the product under test between consecutive tests so that you are measuring the level at which the receiver can lock to the transmitted signal. It generally takes a stronger signal to lock the receiver, than to decode the data once locked.

My interpretation of A/74 is that it suggests tests at D= - 68 dBm would somehow validate receiver performance at threshold, and that testing at – 28 dBm would validate receiver performance under strong signal conditions. Those Desired Signal power levels were chosen by the ATSC in 1995 to allow the ATTC to test two competing modulation schemes to find which was better suited to North American usage. Those levels were chosen to mask any differences between the tuners incorporated in the two prototype receivers. Now we are seeking to find out how well a given receiver operates under extreme signal levels. This masking effect must be eliminated for your purposes.

Co-Channel Interference (CCI) Between DTV Signals

The ATSC DTV Standard has an inherent property that the Desired signal must be at least 15.2 dB above the Undesired signal on the same channel. This is independent of receiver design so it need not be measured in evaluating DTV downconverters.

Interference Between DTV Signals on First Adjacent Channels (ACI)

The FCC Planning Factors for interference from the lower channel, (n-1), into the higher channel (n) is – 28 dB and from the Upper channel, (n+1) into the other (n) it is – 26 dB. Adjacent channel interference has in the past been due to limited selectivity of receivers. This was the case for radio, AM and FM, and for analog TV decades ago. Poor selectivity would and did give rise to the concept of a Desired-to-Undesired (D/U) ratio to express the limits by which the undesired (U) signal could exceed the desired (D) signal in power without undue interference. This was probably thought to be true also for DTV, however data reported by the ATTC showed for D = - 53 dBm the D/U ratio differed from that measured for D = - 68 dBm. G. Sgrignoli (IEEE Transactions on Broadcasting, March 2003) published his conclusion that Adjacent Channel Interference between DTV signals is not due to poor selectivity, but to those 3rd order intermodulation products which fall in the desired channel. The ATTC data showed that the prototype DTV receiver tested had in fact very good IF selectivity, good enough that it could not have caused the interference measured. Other experts in papers published by in IEEE Transactions on Broadcasting concur with Sgrignoli's finding that 3rd order non-linearity in the tuner of the prototype DTV receiver was responsible. With this knowledge, it became apparent that the interference increases with the third power of the interfering signal, not linearly as with poor selectivity where the same D/U ratio applies over the range of desired signal levels. Tests of ACI should be carried out over the full range of D signal powers that will exist within the coverage area of the transmitter.

While the testing done (1995) by the ATTC was carried out with an RF Test Bed which was always linear (free from 3rd order intermodulation products), such is not the case with DTV transmitters. The FCC has defined an RF Mask to describe the spectrum of such transmitters which can be radiated outside of the assigned channel. As Sgrignoli and others have written, such out-of-channel radiated distortion products fall in the TV channels adjacent to that of the transmitter generating them. In the case of ACI, these sidebands fall into the desired channel which limits the D/U ratio for ideal receivers to – 31.3 dB. This is not far above the FCC D/U of 27 +/-1 dB. The additional 3rd order intermodulation products which are generated in the receiver add to those received from the antenna and their total is the in-channel noise under the desired signal power. Thus, measurement of these 3rd order Intermodulation products which are generated within the DTA downconvertors should be of vital concern to the NTIA. The measurement techniques (for ACI) to be described emulate the real world environment by providing undesired DTV signals which conform with the FCC DTV RF Mask (1998) to make the results accurate.

Measurement Technique for ACI between two DTV signals

Two DTV Exciters are required and two calibrated attenuators and a passive signal combiner are required as shown in Figure 2. As DTV Exciters are extremely linear, their output signal is free of out-of-channel frequency components. These can be conveniently generated for ACI test purposes by slightly overloading a RF amplifier (A_1) shown is Figure 2. The attenuator before A_1 is adjusted to generate the distortion level allowed by the FCC. A second attenuator following amplifier A_1 controls the Undesired signal power (U) fed to the DTA downconverter or other device under test. There is no need to generate out-of-channel distortion products in the desired signal path. The Desired signal power on channel (n) to the receiver under test is set to 3 dB above the measured minimum usable DTV signal power of the receiver under test The undesired signal power to the receiver under test will be set 25 dB above the desired signal on channel (n+1) or 27 dB above in the case of channel (n-1). As this D/U is 1 dB below the FCC D/U the receiver should operate normally. Then the D and U signal levels shall be increased 5dB each, and again the D/U is 1 dB less than the FCC spec. so the receiver should be operating normally. This process is continued up to D = - 33 dBm for which U would be either – 5 or – 7 dBm .ATSC doc. A/74, in Appendix D shows that these powers are the maximum predicted near full power transmitters. Therefore testing above D = - 33 dBm should be done with - 5 or – 7 dBm. Testing up to D = - 8 dBm, U = -5 or -7 dBm should be done.

The above test procedure is a pass/fail test. As the D/U is always 1 dB inside the FCC D/U the receiver should function normally at every D level. Testing with U on both channels (n-1) and (n+1) is warranted because of the significant difference between FCC values for D/U for (n-1) vs (n+1). This set-up is shown in Figure 3.

Testing over the entire dynamic range proposed above is required because receivers may behave quite differently over the range of D signals to be encountered in terrestrial broadcasting.

Testing of ACI with Undesired Signals on both adjacent channels

With interfering signals on both n+/-1 as will be the case for some transmitters in many communities, the interference will be substantially worse. It is only a question of how much worse. As the interference mechanism is non-linear this is difficult to predict so it should be determined experimentally.

Interference Between DTV Signals in the UHF band on Channels which had a Taboo Relationship under Analog TV Rules (TCI)

In planning of the UHF band for terrestrial TV broadcasting (1951) the FCC realized that UHF tuners would have less selectivity than is practical at the lower VHF frequencies. The FCC realized that receivers might be prohibitively expensive to prevent interference if TV stations were as tightly packed in the new UHF band as they are in the VHF bands. This led to the adoption of certain taboo channel relationships. Given an allocation of channel (n) to a community, channels near channel (n) were prohibited. These Taboos were n+/-8, n+/-7, n+/-5, n+/-4, n+/-3, n+/-2 and channels n+/-14, n+/-15.

While these UHF Taboos date back to 1951, and some believe that they are no longer needed because of technological progress in tuner design, the FCC has established D/U ratios for these channel relationships for DTV. These are in Part 73 of the FCC Rules.

These D/U ratios apply to DTV-DTV Taboo Channel Interference. While poor RF selectivity inherent at UHF is the reason why these taboos exist, the concept of a D/U ratio is suspect because strong signals on such channels generate 3rd order intermodulation products, and cross-modulation both of which pass through the IF Filter to the detector where they appear as additional noise under the Desired signal. One strong signal on any channel n+/-2 to n+/-5 may cross-modulate the desired signal on channel n. Two strong signals on channel pairs n-6, & n-3 or n-4, & n-2, or n-2 & n-1 or on channels n+1 & n+2, n+2 & n+4, n+3 & n+6 or n+5 & n+10 will generate 3rd order intermodulation products some of which fall in the desired channel (n). These act like additional noise in the desired channel.

No tests with pairs of undesired DTV signals on any of these channel pairs were authorized by the ATSC and none were conducted by the ATTC in 1995. The relative importance of cross-modulation (1 Undesired signal only) vs 2 Undesired signals (for intermodulation) on these channel pairs is unknown.

Moreover, recently Tuners implemented as an Integrated Circuit (Tuner-on-a-chip) for DTV receivers have been announced and are believed to soon be in production. It is hard to imagine how RF selectivity can be provided in the tight space confines of an IC substrate. RF selectivity has generally been a feature of tuners in analog TV receivers. This feature is sometimes called a tracking filter.

Taboo Channel Interference Testing appears to be of extreme importance as most DTV transmitters operate in the UHF band (channels 14 – 51 as of February, 2009). Many of these transmitters operate on a previously vacant channel due to the analog TV UHF Taboos explained above.

Single Taboo Testing for TCI

This procedure follows that for Adjacent channel testing with one exception, the FCC D/U ratios are the same for both n-2 and n+2 and the same applies for n-3 & n+3 etc. The FCC D/U apply to all possible D levels, that is up to – 5 dBm but the maximum U levels is also -5 dBm so in effect the real world D/U goes to 0 dB at D = U = -5 dBm.

Testing might extend from D = - 53 dBm to D = -5 dBm as below D = - 53 dBm, these non-linear interference mechanisms operate weakly.

Double Taboo Testing for TCI

The test set-up shown in Figure 2 applies also to these tests.
The Desired channel (n) carries a test program of video + audio. The Undesired DTV signals shall carry different program material so they are not *correlated*.
These Undesired signals will be carried on these channel pairs:

n-6 & n-3	n+3 &n+ 6
n-4 & n-2	n-2 & n+ 4
n-2 & n-1	n+1 & n+ 2
	n+5 & n+10

3rd order Intermodulation products from the n+5 & n+10 channel pair fall in both the desired channel (n) and the image frequency channel (n+15) of receivers with an IF of 44 MHz and no RF selectivity (tuners-on-a-chip designs may not have little or no RF selectivity).

Testing should cover the same desired signal power range as in single Taboo testing above.

These are both pass/fail tests for that reason FCC D/U ratios should be offset by say 2 dB that is, U reduced 2 dB relative to D so that if the receiver under test passes these tests, it is able to operate to within 2 dB of the FCC D/U ratios in Part 73 of the FCC Rules.

It is my intention to actually perform these tests in my own laboratory in the next few months. I would be pleased to share those results with the NTIA. I should note that is unsponsored research on my part. There is no financial support, and none is being sought or is expected.

Further reading bearing on this topic:

1. "Interference mitigation for improved DTV reception", Rhodes C.W. Sgrignoli G.J. "IEEE Transactions on Consumer Electronics, May, 2005, Volume 51, Issue 2, pages 463-470
2. "Interference to DTTV Reception by First Adjacent Channels", Dr. Oded Bendov, IEEE Transactions on Broadcasting,
3. "Interference between Signals Due to Intermodulation in Receiver Front-Ends", Charles W. Rhodes, IEEE Transactions on Broadcasting DTV Coverage and Service Prediction, O. Bendov, J.F.X. Browne, C.W. Rhodes, Y Wu and P.Bouchard, IEEE Transactions on Broadcasting, Vol. 47, September 2001.
4. "Planning Factors for Fixed and Portable DTTV" IEEE Transactions on Broadcasting, September 2003.
5. ATTS, Record of Test Results of the Digital Grand Alliance System. October 1995
6. "An Evaluation of the FCC RF Mask for the Protection of DTV signals from Adjacent Channel Interference" Advanced Television Technology Center Inc. Document # 97-06 July 17, 1997
7. "DTV Repeater Emission Mask Analysis", IEEE Transactions on Broadcasting, March 2003 Vol. 49, Number 1.

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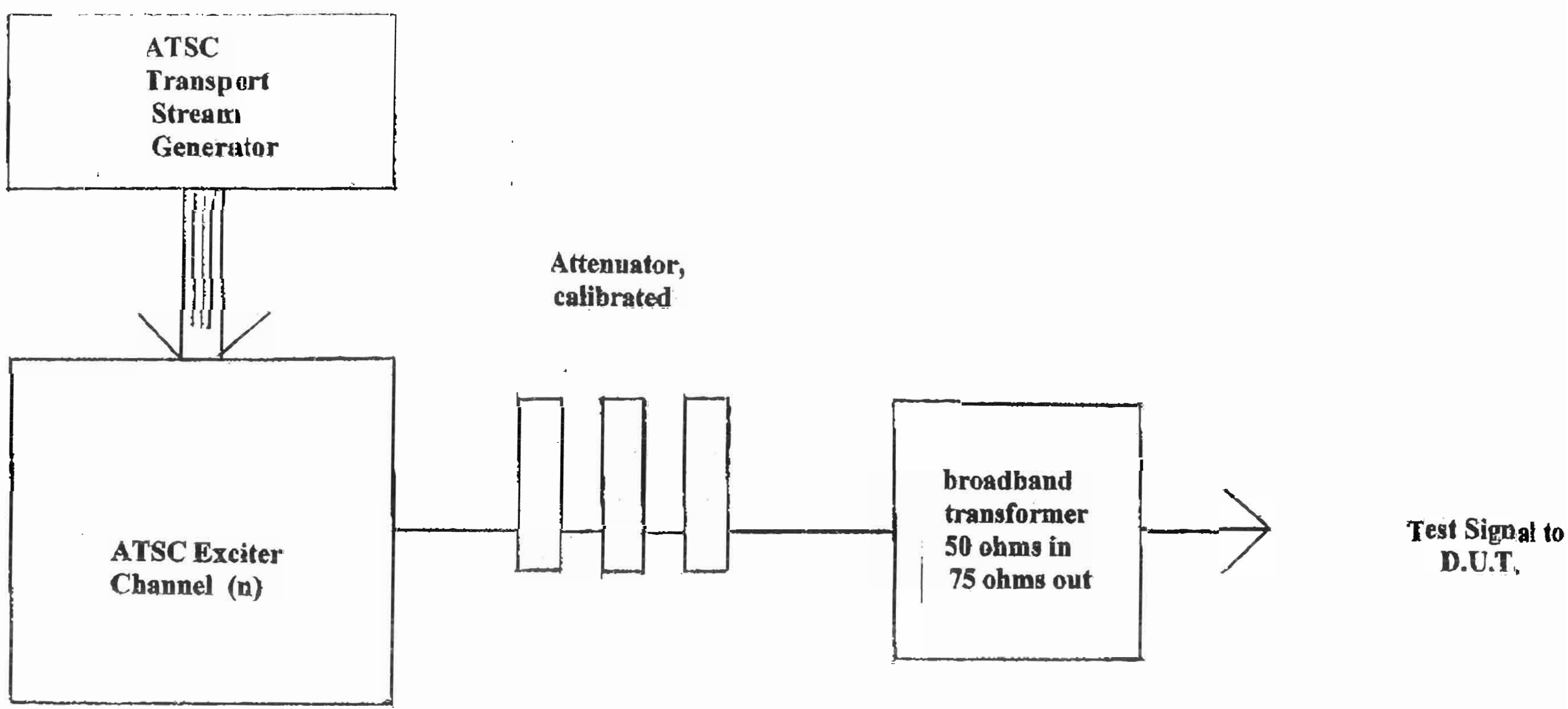

Figure 1: Test Set-up to measure the usable range of received DTV signals

Figure 2: Test Set-up for ACI from either Upper or Lower Adjacent Channel

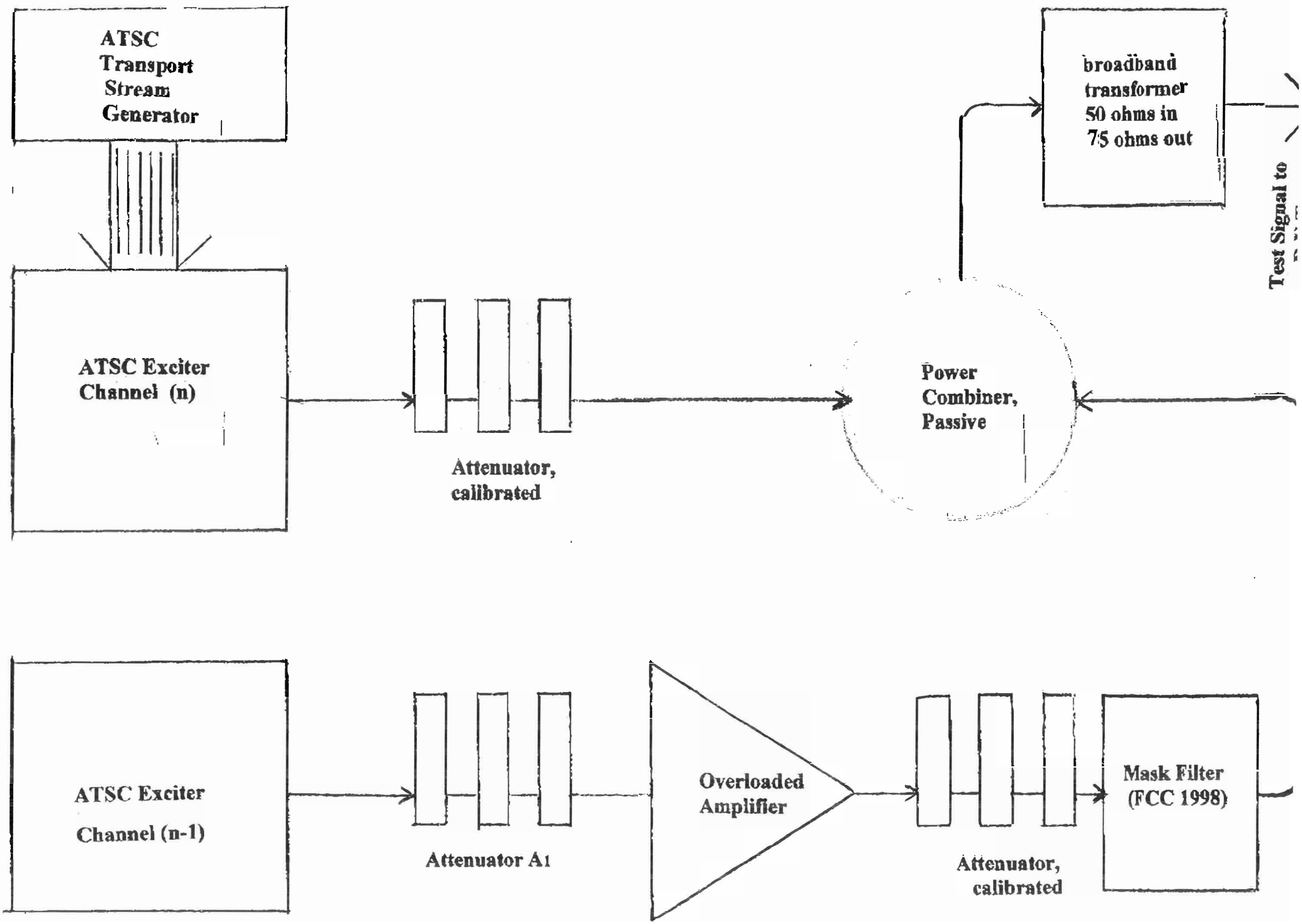

Figure 3: Test Set-up for testing ACI from both Upper and Lower Adjacent Channels