Generation of Confined Spectrum Pulses Using an Absorption PIN Diode Modulator

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ABSTRACT

The PIN diode modulator provides a simple and accurate technique of generating pulses of confined spectrum. From measured amplitude and phase data on a commercially available modulator, the necessary bias input function to give a psuedo-gaussian pulse was computed, and the resultant spectrum was measured and compared to computed spectrum.

SUMMARY

With the rapidly increasing use of the microwave bands, conservation of spectrum has become a prime consideration in the design of new systems and the maintenance of existing ones. One solution to the problem lies with shaped pulses of confined spectrum such as the Gaussian pulses of the VORTAC air navigation system. However realization of the spectral efficiency of a Gaussian pulse requires that the modulated output of the system be arbitrarily close to the true Gaussian shape with little or no angle modulation of the carrier. Since the present high power microwave devices such as klystrons and TWTs rely on transit time, amplitude modulation results in some incidental phase modulation, besides the inevitable distortion in the amplitude function.

Mathematically the spectrum of a symmetric pulse f(t) with phase shift $\varphi(t)$ can be described by the two integrals:

$$A(\nu) = \int_0^{\tau} f(t) \cos \varphi(t) \cos \nu t \, dt$$

$$B(\nu) = \int_0^{\tau} f(t) \sin \varphi(t) \cos \nu t \, dt$$

where

$$|F(\nu)| = \sqrt{A(\nu)^2 + B(\nu)^2}$$

ω = radian frequency

ω_c = radian carrier frequency

$\nu = (\omega - \omega_c)$

Performing the above integration numerically on a digital computer makes it a simple matter to investigate the effect of amplitude distortion and phase modulation on the spectrum. [1] as can be seen in Fig. 1, a linear phase versus amplitude function causes a general widening of the spectrum. This computation assumed perfect Gaussian amplitude down to 0.001% of the peak amplitude. In practical devices the non-linearity in the amplitude characteristic of amplifiers and modulators makes it necessary to consider the problem of tolerable deviation from Gaussian amplitude. Cosine to the Nth pulses provides excellent approximating functions to study the sensitivity of spectrum with respect to amplitude distortion. Table 1 provides a comparison of cosine to the Nth and a true Gaussian, and illustrates that as N increases the cosine to the Nth systematically approaches the Gaussian. The shape of the spectrum shown in Fig. 2 shows the sensitivity of the spectrum to minor differences in amplitude, and, as in the time domain, the spectrum of the cosine to the Nth approaches that of the Gaussian with increasing N.

Historically, modulation has been done at the final stage in order to improve efficiency. As was discussed earlier power microwave devices are transit time oriented by nature; therefore phase modulation is inherent in any attempt at amplitude modulation of the final amplifier. If the output P.A. is used as a linear amplifier, significant improvements in phase characteristics are made at the expense of efficiency. Also, freedom in the method of modulation is gained. An absorption PIN diode modulator was chosen as one means of low level modulation, because of its low phase modulation characteristics.

The phase properties of the PIN diode modulator used (an HP 8731B) were measured using a microwave network analyzer. As seen in Fig. 3, the phase shift is almost negiligible until the amplitude is at least 20 dB down. This data was then processed on a digital computer to determine the shape of the bias pulse which would give a Gaussian envelope. The resulting sequence of points very closely resembled the shape of a cosine squared function, which enabled a simple realization of the bias source!! A HP 3300A function generator with the HP 3302A trigger/phase Lock plug in was used to produce the required current pulse for the PIN diode modulator to within an estimated 3% of the exact pulse predicted. Fig. 4 shows the bias current pulse which yields a 3.1 µS nearly gaussian envelope pulse at the output of the PIN diode modulator. However, as was seen in Fig. 2, the spectrum of an almost Gaussian pulse is not necessarily Gaussian, but the measured spectrum of the output signal shown in Fig. 5 was within 2 dB of a Gaussian pulse through the first 40 dB. The measured spectrum also agreed very closely with a computed spectrum found by Lagrange interpolation [2] of both the amplitude and phase points from the network analyzer data and digital Fourier integration of the resultant waveform.

Comparing this spectrum performance with the spectrum of a VORTAC transmitter [3], the superior performance of absorption modulation can readily be seen. This would indicate that system improvements should be based on linear amplification in the output amplifier and absorption modulation at low level. It also can readily be been that by using digital computation techniques, system performance can be accurately and inexpensively evaluated.

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REFERENCES

[1] Saponas, Thomas A., "Computation of the Microwave Spectrum of Gaussian Envelope Pulses with Phase Modulation," Student Supplement to 1970 IEEE Electromagnetic Compatability Symposium Record.

[2] Carnahan, W., Luther, H., Wilkes, J., APPLIED NUMERICAL METHODS, Wiley, New York, 1969, pp.

[3] Ashley, J. R., "Klystron Amplifiers for TACAN and VORTAC," SPERRY ENGINEERING REVIEW, Vol. 17, No. 3, Fall 1964, pp. 20-24.

NORMALIZED TIME	N = 2	N = 4	N = 6	N = 8	N = 10	GAUSS
	AMPLITUDE FOR COSINE TO THE NTH POWER					
0.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
.03	.9978	.9976	.9976	.9976	.9976	.9975
.06	.9911	.9906	.9904	.9903	.9903	.9901
.09	.9801	.9790	.9786	.9784	.9783	.9778
.12	.9649	.9629	.9622	.9619	.9617	.9609
.15	.9455	.9426	.9416	.9411	.9407	.9395
.18	.9222	.9182	.9168	.9161	.9157	.9141
.21	.8951	.8900	.8883	.8875	.8870	.8849
.24	.8645	.8585	.8564	.8554	.8548	.8524
.27	.8307	.8238	.8215	.8204	.8197	.8170
.30	.7939	.7864	.7840	.7828	.7821	.7792
.33	.7545	.7464	.7443	.7431	.7423	.7394
.36	.7129	.7053	.7029	.7017	.7010	.6981
.39	.6694	.6624	.6602	.6591	.6585	.6559
.42	.6243	.6185	.6167	.6158	.6153	.6132
.45	.5782	.5741	.5728	.5722	.5718	.5704
.48	.5314	.5296	.5290	.5287	.5285	.5279
.51	.4843	.4853	.4856	.4858	.4859	.4862
.54	.4373	.4418	.4431	.4437	.4441	.4455
.57	.3909	.3993	.4018	.4029	.4036	.4062
.60	.3455	.3582	.3619	.3637	.3647	.3686
.63	.3014	.3189	.3238	.3262	.3275	.3327
.66	.2591	.2815	.2877	.2907	.2924	.2989
.69	.2190	.2462	.2538	.2573	.2594	.2671
.72	.1813	.2134	.2222	.2263	.2287	.2376
.75	.1464	.1831	.1930	.1976	.2002	.2102
.78	.1147	.1553	.1662	.1713	.1742	.1851
.81	.0865	.1302	.1419	.1473	.1505	.1622
.84	.0618	.1077	.1201	.1258	.1291	.1414
.87	.0411	.0879	.1006	.1065	.1099	.1226
.90	.0245	.0706	.0834	.0894	.0929	.1058
.93	.0129	.0556	.0684	.0744	.0779	.0909
.96	.0039	.0430	.0554	.0613	.0648	.0777
.99	.0002	.0325	.0444	.0501	.0534	.0660
1.02	0.0000	.0239	.0350	.0405	.0437	.0559
1.05	0.0000	.0171	.0273	.0323	.0354	.0470
1.08	0.0000	.0118	.0209	.0256	.0284	.0394
1.11	0.0000	.0078	.0157	.0200	.0225	.0328
1.14	0.0000	.0048	.0116	.0154	.0177	.0272
1.17	0.0000	.0028	.0084	.0117	.0138	.0225
1.20	0.0000	.0015	.0059	.0088	.0106	.0185
1.23	0.0000	.0007	.0041	.0065	.0080	.0151
1.26	0.0000	.0003	.0027	.0047	.0060	.0123
1.29	0.0000	.0001	.0017	.0033	.0045	.0099
1.32	0.0000	.0000	.0011	.0023	.0033	.0080
1.35	0.0000	.0000	.0006	.0016	.0023	.0064
1.38	0.0000	0.0000	.0004	.0011	.0017	.0051
1.41	0.0000	0.0000	.0002	.0007	.0011	.0040
1.44	0.0000	0.0000	.0001	.0004	.0008	.0032
1.47	0.0000	0.0000	.0000	.0003	.0005	.0025
1.50	0.0000	0.0000	.0000	.0002	.0003	.0020

Table 1

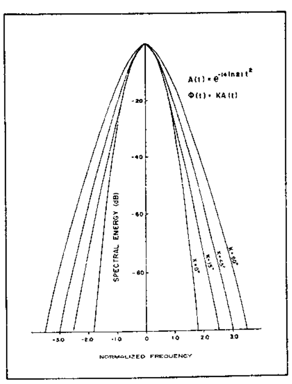

Figure 1. Spectra of Gaussian Pulses With Linear Phase Shift.

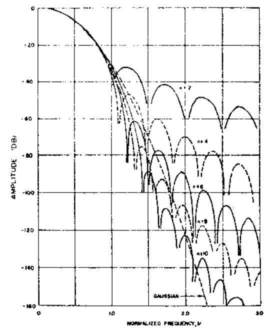

Figure 2. Spectra of Cosine to The Nth Pulses with No Phase Shift.

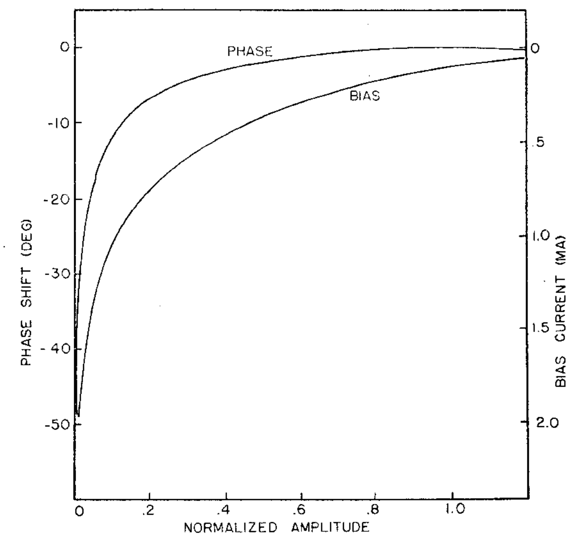

Figure 3. Characteristics ofa a HP 8731B PIN Diode Modulator

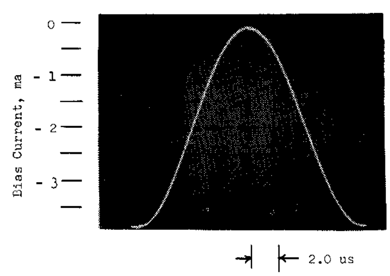

Fig. 4. Bias current pulse supplied to a PIN diode modulator to generate a nearly Gaussian envelope 3.1 μs pulse at the output.

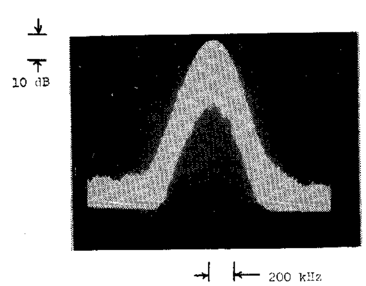

Fig. 5. Measured spectrum at the output of the PIN diode modulator with the envelope adjusted to 3.1 μs nearly Gaussian shape.

Notes