

# Bandwidth of Angle Modulated Waves

$$\varphi_{FM}(t) = A \cos[\omega_c t + k_f a(t)] \quad \text{where} \quad a(t) = \int_{-\infty}^t m(\alpha) d\alpha$$

$$\varphi_{FM}(t) = A \operatorname{Re}[e^{j[\omega_c t + k_f a(t)]}] = A \operatorname{Re}[e^{j k_f a(t)} e^{j \omega_c t}]$$

Expand  $e^{j k_f a(t)}$  using power series expansion

$$\varphi_{FM}(t) = A \operatorname{Re} \left[ \left\{ 1 + j k_f a(t) - \frac{k_f^2}{2!} a^2(t) + \dots + j^n \frac{k_f^n}{n!} a^n(t) + \dots \right\} e^{j \omega_c t} \right]$$

$$\varphi_{FM}(t) = A \left[ \cos \omega_c t - k_f a(t) \sin \omega_c t - \frac{k_f^2}{2!} a^2(t) \cos \omega_c t + \frac{k_f^3}{3!} a^3(t) \sin \omega_c t + \dots \right]$$

The bandwidth of  $a(t)$ ,  $a^2(t)$ ,  $a^n(t)$  are  $B$ ,  $2B$ , and  $nB$  Hz, respectively. From the above equation it seems the bandwidth of angle modulation is infinite but for practical reason most of the power reside at  $B$  Hz since higher terms have small power because of  $n!$ .

## Modulated Waves

**SA Adler**



## Modulated Waves:

Modulated Waves L. A. Ostrovskii,Alexander I. Potapov,1999 Lev Ostrovsky and Alexander Potapov consider linear and nonlinear waves such as solitons waves in inhomogeneous media and many others They discuss modulated waves those characterized by a slow variation of the macroscopic parameters of amplitude frequency and profile    An Electron Tube Transmitter of Completely Modulated Waves Lewis Madison Hull,1920    On the Spectrum of Frequency-modulated Waves and Its Bounds Franklin Chung-chi Lei,1971    Ground Radio Communications Specialist (AFSC 30454): Communications circuits Francis J. Drollinger,1984    Scientific Canadian Mechanics' Magazine and Patent Office Record Canada. Patent Office,1918    Year Book Institute of Radio Engineers,1929    The Canadian Patent Office Record and Register of Copyrights and Trade Marks ,1925    Radio World ,1922    Telephone Engineer & Management ,1923    Wireless World ,1927    **The Wireless World and Radio Review** ,1925    Radio News ,1923 Some issues 1943 July 1948 include separately paged and numbered section called Radio electronic engineering edition called Radionics edition in 1943    Radio Engineering Principles Henri Lauer,Harry Leonard Brown,1928    **Household Physics** Walter George Whitman,1924    **Radio Engineering** ,1928    **Radio & Model Engineering** ,1930    **College Physics** Alexander Wilmer Duff,1926    **The Drift of Civilization** St. Louis post-dispatch,Charles Greeley Abbot,1929    **The New International Encyclopaedia** Frank Moore Colby,Talcott Williams,1922    **The New International Encyclopaedia** ,1929

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