Here is θ_d the dipole transversal spatial angle designating a ***direction*** $\mathbf{e}_{\theta_d} \| \odot \perp \mathbf{e}_3 \| \vec{\omega}$.
Then the macroscopic field with an amplitude $E_a(x_3)$ as in (3.251) is written

$$\vec{E} = E_\omega(t_c, \Delta\phi)\,\mathbf{e}_{\theta_d} = E_a(x_3) 2\cos\big(\omega_c t_c + \Delta\phi(t_c) - k_{c,3}x_3\big)\,\mathbf{e}_{\theta_d} \quad (3.274)$$
$$= E_{\omega_{\rm FM}}(t_c, x_3)\,\mathbf{e}_{\theta_d} = E_a(x_3) 2\cos\big(\omega_{\rm FM} t_c - k_{c,3}x_3\big)\,\mathbf{e}_{\theta_d}$$

The hereby propagated signal has carrier frequency ω_c as the signal's own reference.
The common development parameter t_c obtained by 'counting' the reference phase ϕ_c for the carrier, that $t_c = |\phi_c|/|\omega_c|$. Both of them $\omega_c[\widehat{\omega}]$ and $t_c[\widehat{\omega}^{-1}]$ stand preferable in relative reference to an external standard frequency $|\widehat{\omega}| \equiv 1\,[\widehat{\omega}]$.

3.5.2.4. Amplitude Modulation at Mutual Frequencies

The formulas (3.260) to (3.262) give the condition for coherent modulation of a monochromatic carrier wave $\big|\psi^{\rm macro}_{\Sigma\pm\vec{\omega}_c\perp\odot}(t_3)\big\rangle = N(m)\odot 2\tilde{r}(\rho)\, e^{\pm i(\omega_c t_3 - 2\pi m)}$
However, intuit we have an arbitrary modulation signal as a ***spectrum*** after the Fourier method[144]

$$m(t) = \int_{\mathbb{R}} \tilde{m}(\omega) e^{-i\omega t}\, d\omega\,, \quad \text{complemented by} \quad \tilde{m}(\omega) = \frac{1}{2\pi}\int_{\mathbb{R}} m(t) e^{i\omega t}\, dt. \quad (3.275)$$

For the individual modulation frequencies $\omega_{\rm m}$ we form a ***spectrum*** modulation factor[145]

$$\tilde{m}_a(t_c, \omega_{\rm m}) e^{i\omega_{\rm m} t_c}, \quad (3.276)$$

which depends on a carrier chronometer time $\{t_c\}$. The modulated wave is written as

$$W^{\rm helix}_{\pm\omega_c,\omega_m}(t_c, x_3) = \tilde{m}_a(t_c, \omega_m) e^{\pm i\omega_m t_c} \boldsymbol{A}_{\rm A} \boldsymbol{A}_{\rm loss}(x_3) \big(e^{\pm i(\omega_c t_c - k_{c,3}x_3)}\big)_{\perp\mathbf{e}_3} \quad (3.277)$$
$$= \tilde{m}_a(t_c, \omega_m) \boldsymbol{A}_{\rm A} \boldsymbol{A}_{\rm loss}(x_3) \Big(e^{\pm i((\omega_c + \omega_m)t_c - k_{c,3}x_3)}\Big)_{\perp\mathbf{e}_3}$$

For a macroscopic field from a dipole in the angular ***direction*** $\mathbf{e}_{\theta_d}$, this becomes

$$\vec{E} = E_{\pm\omega_c,\omega_m}(t_c, x_3)\,\mathbf{e}_{\theta_d} = \tilde{m}_a(t_c, \omega_m) E_a(x_3) 2\cos\big((\omega_c + \omega_m)t_c - k_{c,3}x_3\big)\,\mathbf{e}_{\theta_d} \quad (3.278)$$

Wherein the amplitude factor is given by $E_a(x_3) = 2\boldsymbol{A}_{\rm A}\boldsymbol{A}_{\rm loss}(x_3)$ and $\boldsymbol{A}^- = \boldsymbol{A}^+$ for the dipole field. We see here that the arbitrary amplitude variation implies an accompanying modulation of frequency. Thus, all randomly modulated waves include a ***spectrum*** of ***subtons*** with a range of mutual angular frequency energies $\omega_c + \omega_m$.

3.5.2.5. QAM Modulation

The modern modulation is called Quadrature Amplitude Modulation (QAM). Based on the idea of different carriers (OFDM) both phase and amplitude modulated the waves of these ***subtons***.
The technical method of controlling the phase modulation is called quadrature. This is in an ontological intuition divide it into a Cartesian coordinate system of real and imaginary parts and an amplitude signal modulates these separately, QAM.
Modulation is done digitally through two DAC (digital analogue converters) and the bandwidth is increased by the OFDM FFT^{-1} method, which is outside of this review.
Hereby I finally conclude the methods of signal modulation of a transversal plane wave of ***subtons*** in the transfer of information.
Two basic quantities that can be modulated:

- One is the angular frequency energy $\omega(t_c) = \omega_c + \Delta\phi(t_c)/\omega_c$ through the phase angle of the wave.
- The other is the amplitude due to the number of intensities of subtons being created $N_\omega(t_c)$.

The ontology of a combined modulated macroscopic signal may be formulated as simple as

[144] See (3.254) and (3.255) and § 1.7.7-0, and later below § 4.1.4.2 The Vector Space of Fourier Integrals.
[145] The modulation factor is normally considered arbitrary within the framework $0 \ll m_a(t_c, \omega_{\rm m}) \leq 1$ and $0 \leq |\omega_{\rm m}| < |\omega_c|$, (where 0≪, means over the noise, 0<noise<).

$$W_{\pm\vec{\omega}_c}({\rm QAM}(t_c)) = W_{\pm\vec{\omega}_c}\big(\Delta\phi(t_c), N_{\pm\omega}(t_c)\big) \quad (3.279)$$
$$\Leftrightarrow \quad N_{\pm\omega}(t_c)\odot 2\tilde{r}(\rho) e^{\pm i(\omega_c t_c + \Delta\phi(t_c))} = N_{\pm\omega}(t_c) ⊚ e^{\pm i\omega(t_c)t_c}.$$

Carrier reference has no other purpose than to set out the ***direction*** $\vec{\omega}_c$ of the signal and form the basis for the carrier chronometer $\{t_c\}$. It need not even be created in the signal itself but must be used as an external reference frequency $\omega_c\,[\widehat{\omega}]$ for the signal as a ***spectrum*** of ***subtons***.
In practise, a signal transmitter needs a clock oscillator and a receiver has to synchronise to that clock to interpret the signal information from A to B. (synchronised relativistic Doppler shift included)

3.5.2.6. The Two Helicities

As creations $a^\dagger_{\odot+\omega}$ and $a^\dagger_{\odot-\omega}$ are independent, and thus the Fourier frequencies $+\omega$ and $-\omega$ orthogonal, the two signals $W^{\rm helix}_{+\vec{\omega}}$ and $W^{\rm helix}_{-\vec{\omega}}$ transmit each information in the same channel along $\mathbf{e}_3$, of cause relative to a virtual reference carrier.[146]

3.5.3. Elliptical Polarisation

We write the formula for a modulated elliptically polarized transversal plane wave from (3.277) and (3.278)

$$W^{\rm elliptic}_{\pm\omega_c,\omega_m}(t_c, x_3) = \tilde{m}_a(t_c, \omega_m) \boldsymbol{A}_{\rm loss}(x_3) \big(\boldsymbol{A}^+_{\rm A} e^{+i((\omega_c+\omega_m)t_c - k_{c,3}x_3)} + \boldsymbol{A}^-_{\rm A} e^{-i((\omega_c+\omega_m)t_c - k_{c,3}x_3)}\big) \quad (3.280)$$
$$= \tilde{m}_a(t_c, \omega_m) \boldsymbol{A}_{\rm loss}(x_3) \Big(\boldsymbol{A}^{\rm dipol}_{\rm A} \cos\big((\omega_c+\omega_m)t_c - k_{c,3}x_3\big) + \boldsymbol{A}^{\pm\rm helix}_{\rm A} e^{\pm i((\omega_c+\omega_m)t_c - k_{c,3}x_3)}\Big)$$

wherein the circulating part is $\boldsymbol{A}^{\pm\rm helix}_{\rm A} = |\boldsymbol{A}^+_{\rm A} - \boldsymbol{A}^-_{\rm A}|$ and the dipole part $\boldsymbol{A}^{\rm dipol}_{\rm A} = \boldsymbol{A}^+_{\rm A} + \boldsymbol{A}^-_{\rm A} - \boldsymbol{A}^{\pm\rm helix}_{\rm A}$ demands the major axis of the ellipse which has the same ***direction*** $\mathbf{e}_{\theta_d}$ as the dipole component in the transversal plane. Here we recall that modulation occurs in relation to a carrier $\vec{\omega}_c$ with the chronometer $\{t_c\}$.

3.5.3.2. The Elliptical Polarized Monochromatic Transversal Plane Wave

Now we return to an intuition of a single angular frequency $\vec{\omega} = \omega\mathbf{e}_3\,[\widehat{\omega}]$, of the ***direction*** $\widehat{\vec{\omega}} \parallel \vec{\omega}$, which of course has a reference to an external frequency $\widehat{\omega} \equiv 1$, and here we look at the same frequency and the same ***direction*** for all ***subtons*** created simultaneously.
The development parameter $t\,[\widehat{\omega}^{-1}]$ is that factor with our reference $\widehat{\omega} \equiv 1\,[\widehat{\omega}]$, that transforms $\omega\,[\widehat{\omega}]$ to the internal quantum mechanical phase angle development $\phi = \omega t + \theta_n$ in the ***subtons*** $\Psi_{\omega,n}$.
Here we imagine controlling the phase difference θ_n between the simultaneously created ***subtons***.
To analyse the simultaneous wavefront in this transversal plane monochromatic wave with elliptical polarization as in (3.280) we divide (3.229) in a linear polarized part and a circularly polarized part by finding the predominance $M = |N_+ - N_-|$ between the progressive N_+ and retrograde N_- rotation, as well as a balance between the two $N = ½(N_+ + N_- - M) = \min(N_+, N_-)$. The elliptical wave state is then

[146] If this seems mysterious, I just point out that this has been widely used in radio communication with helix antennas, one example is the Telstar satellite in 1962 etc. It is remarkable when America to Japan later tried this first it would not work due to a misunderstanding about the progressive rotation of whether to transmit or to receive.

For quotation reference use: ISBN-13: 978-8797246931